Micronekton - What are they and why are they important?

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Background

Micronekton are relatively small but actively swimming organisms ranging in size between plankton (< 2 cm), which drift with the currents, and larger nekton (> 10 cm), which have the ability to swim freely without being overly affected by currents. Although there are some precise definitions based on Reynolds numbers, micronekton may be operationally defined as taxa too vagile to be caught with conventional plankton nets and too small to be retained by most large-meshed trawls. Micronekton are diverse taxonomically. The principal groups include the cephalopods (small species and juvenile stages of large oceanic species), crustaceans (including adult euphausiids, pelagic decapods and mysids), and fishes (mainly mesopelagic species and juveniles of pelagic nekton). Although not generally fished commercially because of their relatively small size and high lipid content, mesopelagic fishes represent a substantial biomass in oceanic waters and are a critical but poorly understood intermediate trophic link between the mesozooplankton and the higher trophic levels including fishes, seabirds and marine mammals. Many studies have shown that micronektonic species are a primary food source for a wide variety of harvested nektonic species.

Fig. 1 Diversity of life forms considered as micronekton.

Many micronektonic species can be found close to shore or near the sea surface (*e.g.*, Abookire *et al.*, 2002, *Fish. Bull. U.S.*, 100: 376-380), but most occur in the midwater pelagic realm mainly at the edge of, or beyond the continental shelves. Indeed, micronekton are one of the most conspicuous and ecologically-important components of the vast mesopelagic zone of the world's oceans, arguably the largest and one of the least variable ecosystems on the planet. This dark, cold, and relatively unproductive system extends from around 200 m to depths greater than 1000 m, and many of these organisms have evolved unique adaptations to this environment (Fig.1). Most mesopelagic micronektonic organisms undertake extensive vertical migrations on a daily basis, occupying the productive surface waters at night and descending to midwater during the daytime to reduce predation. Diel vertical migration of micronekton has been shown to contribute significantly to the rapid vertical transport of organic material from epipelagic to mesopelagic zones, referred to as the biological pump, where carbon fixed as living organic matter plus anthropogenic substances, such as insecticides and pollutants, are transported to deep-sea ecosystems. These micronektonic organisms in turn may be consumed by epipelagic predators in the near-surface waters, large nekton such as tunas, sharks and swordfishes that migrate dielly with the micronekton, and deep-sea fishes that migrate up to midwater. All of these predators capitalize on this vast and highly predictable food source.

Despite their importance to many consumers in the ocean, relatively scant attention has been paid to micronekton as a whole, especially compared to the primary consumer and top trophic levels that they link. Much of what is known and published in the literature was generated in the 1960s and 1970s and was not synthesized in any manner. A need was identified within the PICES community, especially among the ecosystem modelers, for a summary of the available information on micronekton in the North Pacific. In response to this, a scientific session dedicated to micronekton was held during the 1997 PICES Annual Meeting in Pusan, Korea, that brought together a large number of experts within the North Pacific region. It was at that time that a proposal was put forth to establish a PICES Working Group to assimilate knowledge of micronekton and their sampling in the North Pacific. This led to the formation of Working Group 14 (WG 14) on *Effective sampling of micronekton* which met for the first time in 2000. Initial summaries of the sampling conducted by each member nation were contained in a report presented at the PICES/CoML/IPRC workshop on "Impact of climate variability on observation and prediction of ecosystem and biodiversity changes in the North Pacific" held in Honolulu, in March 2001 (Brodeur, 2001, *PICES Sci. Rep.*, 18: 86-90). Prior to the 2000 PICES Annual Meeting in Hakodate, Japan, WG 14 co-sponsored a symposium on "Advanced techniques of sampling gear and acoustic surveys for estimation of fish abundance and

behavior", the proceedings of which has since been published electronically and available from Hokkaido University (Iida, 2003). The final report of that group (Brodeur and Yamamura (Eds.), 2005, *PICES Sci. Rep.*, **30**) synthesizes what is known about the distribution, biomass, growth, reproduction, and trophic relationships of micronekton in the North Pacific Ocean and adjacent seas, with a summary of the present state of sampling of these organisms. It also attempted to identify key knowledge gaps that should be filled in the coming years.

Included in the terms of reference was a request to examine the efficacy of available micronekton sampling gears and propose new sampling devices if the available ones were not adequate for the task. One of the recommendations included in the WG 14 report is that although a number of gears are presently being used to sample micronekton in the North Pacific and other parts of the world's oceans, there has been little effort expended in comparing the relative sampling efficiency and selectivity of these gears. The merits and shortcomings of many different gear types for sampling micronekton have been discussed at length in reports and publications arising from the SCOR Working Group on *Methods of Sampling Micronekton* (Pearcy, 1981, *Biol. Oceanogr*., 2(2-4): 1-456). In most studies, only one type of gear was used so it is impossible to deduce the various biases associated with each gear. Moreover, sampling gears have become more advanced in time (see review by Wiebe and Benfield, 2003, *Prog. Oceanogr*., 56: 7-136) and the older technologies have been abandoned, often without any inter-calibration with the gears that replace them. This has hampered efforts to look at inter-decadal or even regional comparisons of micronekton composition and biomass since very often, different gears are used.

As a result of the recommendations of WG 14, PICES formed an Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) in 2002, to conduct a field study to compare micronekton sampling gears and other quantifying technologies such as acoustics and visual sampling methods, similar to that done by the International Council for the Exploration of the Sea (ICES) in the North Atlantic Ocean utilizing mainly plankton gears (Wiebe *et al.*, 2002, *ICES Coop. Res.*, 250, 25 pp). The role of MIE-AP was to oversee planning and implementation of the field program and dissemination of the results to the scientific community.

Initial field work

A preferred location is thought to be one that is known to contain high densities of all major micronektonic categories (midwater fishes, cephalopods, and crustaceans), and thus it would have to be an area that has been sampled previously to a great extent. It should also be an area that is relatively uniform over various spatial and temporal scales, and exhibits a high degree of repeatability among repeat tows taken at the same station, so that the majority of variability between tows could be ascribed to gear differences. It is desirable that the ocean conditions in the study area be relatively calm to facilitate deployment and recovery of complex gear types. Finally, the station should be in relatively deep water but also close to shore to minimize transit time. Although there are several areas within the PICES region that meet these requirements, the one recommended by MIE-AP is the area off the Hawaiian Islands. A pilot cruise was organized by the Panel to occur just prior to the PICES Annual Meeting in Honolulu to take advantage of the possibility that many potential participants would be attending the meeting. The leeward side of Oahu was chosen as the location for the experiment for several reasons including the benign weather conditions and relatively homogeneous distribution of the target taxa.

Ship time was secured on the NOAA research vessel, the *Oscar Elton Sette*, based in Honolulu, Hawaii. This vessel is over 70 m long and has the capability to tow large dual-warp trawls requiring doors as well as large and small single-warp midwater trawls. The ship also has several additional oceanographic winches equipped with conducting cable and sufficient deck space to stage several gear types. It also has advanced acoustic and oceanographic sampling capabilities needed for such a study.

An international team of experts in micronekton taxonomy and sampling and acoustics (Table 1) was assembled for the cruise, and the ship sampled continuously for seven days, alternating among three different gears (Fig. 2): a 140 m^2 pelagic Cobb trawl, a 4 m^2 Hokkaido University Rectangular Frame Trawl (HN), and a 2-m Midwater Trawl (IKMT). Sampling was conducted entirely during daylight and night periods, avoiding the crepuscular migration periods when the mesopelagic layer was in flux. Daytime

Table 1 Micronekton inter-calibration experiment cruise participants.

Organization/Institute	Name
Institute of Ocean Sciences, Fisheries & Oceans, Canada	Douglas Yelland
Earth & Ocean Sciences, University of British Columbia, Canada	Evgeny Pakhomov Larissa Pakhomova
Graduate School of Fisheries Sciences, Hokkaido University, Japan	Masayuki Abe Hiroki Yasuma
Pacific Islands Fisheries Science Center, National Marine Fisheries Service (NMFS), U.S.A.	Michael Seki (Chief Scientist) Daniel Curran Donald R. Hawn Reka Domokos
Northwest Fisheries Science Center, NMFS, U.S.A.	Richard Brodeur
Harbor Branch Oceanographic Institution, U.S.A.	Andrei Suntsov

Fig. 2 Deployment of the different sampling gears and sorting the catch.

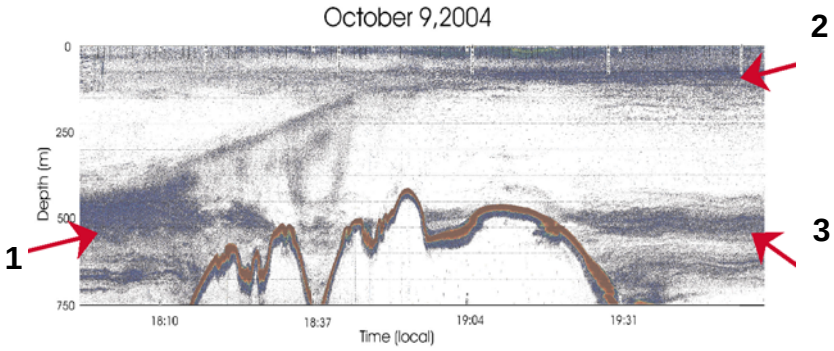

Fig. 3 An EK-60 38 kHz echogram collected from 1800-2000 h on October 9, 2004, showing the dusk migration of the scattering layer from a normal daytime depth around 550 m up to the surface, and the locations of sampling during the micronekton inter-calibration experiment. (1) Day tows ≈ 550 m, (2) Night tows ≈ 120 m, (3) One series night tows ≈ 550 m.

sampling was entirely in a deep layer (typically targeting 550 m), while nighttime sampling was mainly targeted the upper 120 m of the water column, although one series was conducted at depth to sample the non-migratory layer (Fig. 3).

Preliminary results from the cruise were presented at a MIE-AP Workshop convened prior to PICES XIII. It was found that while small sampling gears provided similar micronekton abundances, densities measured using both HN and IKT were generally significantly higher than densities obtained by Cobb trawl for main taxonomic groups sampled during the survey (Fig. 4), in part because these nets had finer mesh sizes than the Cobb trawl. The Cobb trawl, however, caught substantially larger organisms than either of the other gears due principally to its large mouth opening.

Deployment of the three types of gear resulted in a collection of approximately 43-46 species of fishes from 24-25 families. At present, these numbers exclude all representatives of the rather speciose midwater family Myctophidae, which were not identified to species at sea. The majority of fish families (21) encountered during our sampling are truly mesopelagic with only few representatives from coastal and epipelagic communities.

The quantitative composition of the entire fish collection was very uneven, with myctophids contributing close to 60% of all specimens collected. The second most abundant were in the family Gonostomatidae (largely due to

abundant and ubiquitous *Cyclothone* spp.) which totals close to 38% of the total catch. The remaining families contributed less than 4% to the total fish collection.

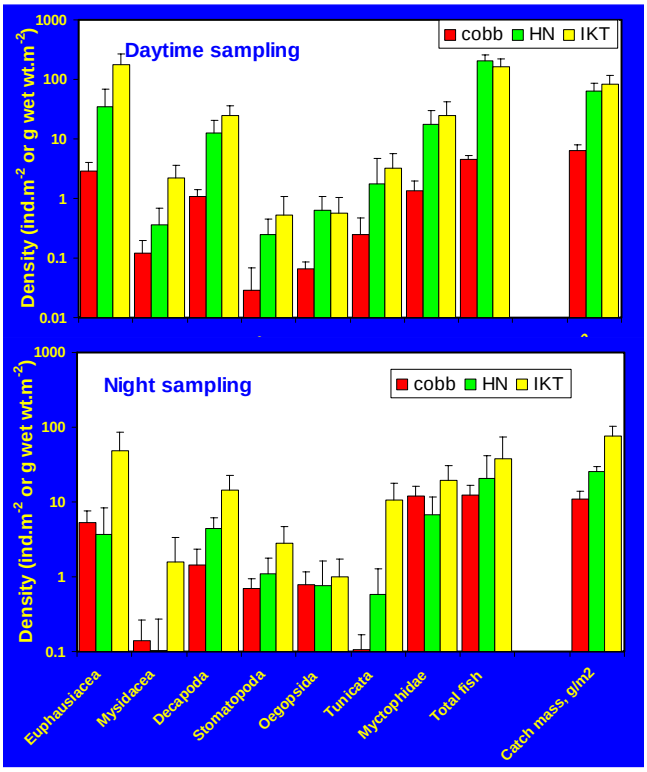

Fig. 4 Comparative catch by three sampling gears of the main taxonomic groups and overall catch biomass during day (top panel) and night (bottom panel) sampling during the inter-calibration cruise.

Based on our preliminary taxonomic treatment, we calculated basic community indices to estimate diversity, evenness and species richness (Fig. 5). As seen for densities of particular midwater groups, these indices are very similar for the HN and IKT gears. This is particularly evident for the number of species and for daytime diversity and evenness indices. Both day and night deployment of the Cobb Trawl clearly procured more species per trawl, which is also reflected in the higher diversity and evenness indices. After completing our taxonomic analysis, we expect to analyze additional data on ichthyoplankton and invertebrate abundances and species composition to complement inter-gear comparison and estimate relative catchability for each gear.

In terms of acoustics, two prominent scattering layers were observed at ~10-140 m and ~450-750 m. The surface layer was due primarily to organisms migrating to the surface at night, while the deep scattering layer was a permanent feature that may be representative of non-migratory organisms and/or organisms that migrate up from deeper water during the night (Fig. 3). The water column between the two prominent scattering layers lacked significant backscatter indicating that the water column was basically devoid of organisms outside the layers, which was verified by a single haul during daytime that fished only the upper 300 m and came back nearly empty.

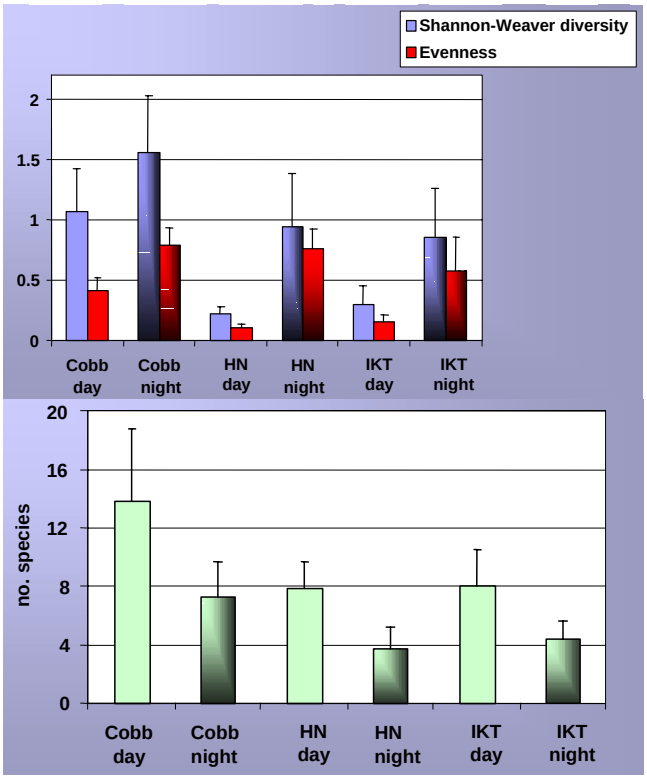

Fig. 5 Diversity and evenness indices (top panel) and total number of species (bottom panel) caught by each sampling gear by time of day.

Future directions

Preliminary analysis from the 2004 experiment indicated that individual gears sampled different, often non-overlapping, size groups of plankton and micronekton. This appeared to be relevant for our ability to interpret the data acquired from the multiple acoustic frequencies. However, it also points out that successful inter-comparisons during future cruises requires a closer scrutiny of gear-types and net mesh sizes prior to the experiment. Adoption of a "standard" sampling gear (such as a Rectangular Midwater Trawl (RMT 1+8) or a 3-m IKMT) and mesh sizes was suggested to facilitate comparisons. Based on the success and preliminary findings of the first cruise, MIE-AP recommended conducting a second experiment within the subarctic North Pacific using a larger variety of micronektonic sampling gears. This cruise is tentatively planned for summer 2005 (or 2006, depending on ship time availability) in the Bering Sea.

Dr. Richard Brodeur (rick.brodeur@noaa.gov) is a Research Fisheries Oceanographer working in the Fish Ecology Division of the Northwest Fisheries Science Center, NOAA Fisheries, and is based in Newport, Oregon. He received his M.S. in oceanography from Oregon State University, and his Ph.D. in fisheries from the University of Washington. Following a postdoc at the Pacific Biological Station in Nanaimo, B.C., Canada, he began his career working on early life history and recruitment dynamics of walleye pollock in the Subarctic Pacific for the Alaska Fisheries Science Center. He returned to Oregon to work on habitat preferences and trophic ecology of juvenile salmon. He has published on a variety of topics ranging from satellite oceanography to fish bioenergetics to fisheries acoustics, but has focused much of his research on micronekton and nekton. Dr. Brodeur is the Co-Chairman of the PICES WG 14 on Effective sampling of micronekton.

Dr. Michael Seki (Michael.Seki@noaa.gov) is the Deputy Director of the Pacific Islands Fisheries Science Center located in Honolulu, Hawaii and has been with NOAA Fisheries since 1980. He has conducted studies on marine resources in the Pacific region including seabirds, sea turtles, tropical snappers, oceanic squid, tunas, and billfishes, and has authored or co-authored over 40 scientific papers on topics such as open ocean food webs (ecosystems) and the influence of the physical oceanographic environment on the distribution and abundance patterns of living marine resources. Mike received his M.S. in oceanography from the University of Hawaii, and his Ph.D. in marine environment and resources from Hokkaido University (Graduate School of Fisheries Science). Dr. Seki is the Co-Chairman of the PICES Advisory Panel on Micronekton sampling inter-calibration experiment.

Dr. Evgeny Pakhomov (epakhomov@eos.ubc.ca) is a Faculty in Biological/Fisheries Oceanography at the Department of Earth and Ocean Sciences of the University of British Columbia, Vancouver, Canada. His research focuses on topics ranging from species ecology, at the level from zooplankton to fish, to ecosystem structure as well as physical-biological and biochemical coupling. Recently, Evgeny has developed interests in the applications of stable isotopes (bulk and compound specific measurements) in food web studies to reconstruct trophic pathways in pelagic ecosystems. He has also published on variability and responses of marine ecosystems to climate change using stable isotopes, large-scale and retrospective analyses. Dr. Pakhomov co-chairs the PICES Advisory Panel on Micronekton sampling inter-calibration experiment.

Dr. Andrey Suntsov (ASuntsov@HBOI.edu) is a Postdoctoral Fellow at Harbor Branch Oceanographic Institution, Florida. After graduating from Moscow State University in 1993, he started work on oceanic ichthyoplankton/mesopelagic fishes at P.P. Shirshov Institute of Oceanology in Moscow. He entered the graduate program at the Virginia Institute of Marine Science, earning his M.S. in 1997. Andrey subsequently returned to Russia and completed his doctorate degree on ichthyoplankton in Peruvian waters in 2003. At present, Andrey is involved in the study of age and growth patterns of deep-sea fishes from the North Atlantic. His research interests encompass early life history of marine fishes, oceanic micronekton and mesopelagic biology.